



Carnegie Mellon
Software Engineering Institute

Pittsburgh, PA 15213-3890

Measuring Systems Interoperability

Conference on the Acquisition of Software-Intensive Systems
January 28-30, 2003

Mark Kasunic

Software Engineering Measurement and Analysis [SEMA]
Software Engineering Institute
mkasunic@sei.cmu.edu

Sponsored by the U.S. Department of Defense
© 2003 by Carnegie Mellon University



Carnegie Mellon
Software Engineering Institute

Presentation Outline

- ❖ Introduction to the Problem
- ❖ SEI's Research Goals
- ❖ Typical Questions
- ❖ Some Definitions
- ❖ Approaches to Measuring Interoperability
 - Scorecard Approach
 - Levels of Information Systems Interoperability (LISI)
 - Management Performance Measures
- ❖ Next Steps

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE JAN 2003		2. REPORT TYPE		3. DATES COVERED 00-00-2003 to 00-00-2003	
4. TITLE AND SUBTITLE Measuring System Interoperability				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Carnegie Mellon University,Software Engineering Institute,Pittsburgh,PA,15213				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 18	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			



The Challenge

Interoperability is the number one problem in joint force & combined operations. It is the CINC's top issue*.

The problem may be getting worse

- Real-world operations, evaluations and exercises continue to highlight joint/combined warfighting capability shortfalls
- As new coalition partners develop, complex systems are acquired, and "fixes" to past problems are applied in stove-piped fashion
- Joint Vision 2010 and 2020 call for increasingly network-centric warfare, dependent upon fully interoperable systems

* As stated by Ms. Robin Quinlan, Deputy Director, Systems Interoperability, Office of the Secretary of Defense [Quinlan, 2000].



Common Measurement Questions

Are we able to identify the root causes of interoperability problems?

Are new system acquisitions becoming more effective at avoiding the same types of interoperability problems that occurred *yesterday*?

How does one quantify interoperability in an actionable way?

How do we measure the tradeoffs between systems interoperability and other fundamental attributes of C4I systems including

- Security
- Survivability
- Performance
- Availability
- Flexibility



SEI Research Goals In This Area

Understand the state of the practice for measuring systems interoperability

- Typical approaches for assessing and measuring interoperability
- Innovations that are currently being explored or piloted for improving the state of the practice

Identify potential measures and validate their usefulness through collaborative field-based investigations

Share the research results with the community



State of the Practice Report

- Based on previously published reports
- Defines interoperability and surveys the issues involved with achieving interoperability
- Reviews current approaches to the interoperability problem
- Highlights a promising new approach to assessing and measuring interoperability – the Levels of Systems Interoperability (LISI) Model
- Reviews other potential measures for measuring various dimensions of interoperability
- Recommends an initial set of measures for improving interoperability

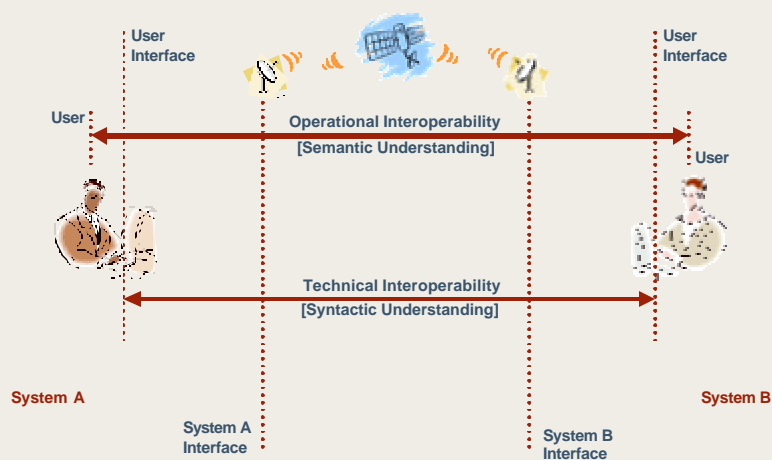
White paper is available at <http://www.psmc.com/>



Interoperability Defined

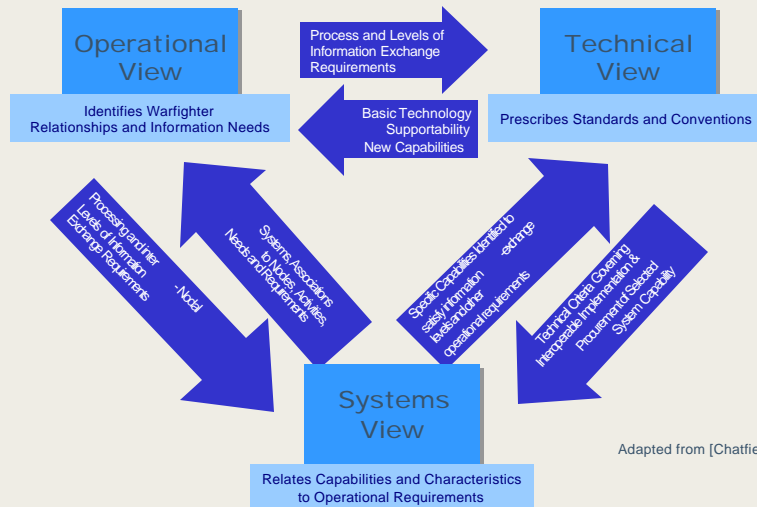


Technical Vs. Operational Interop





Interoperability – Three Views



Adapted from [Chatfield 98]

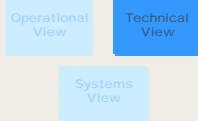


Presentation Outline

- ❖ Introduction to the Problem
- ❖ SEI's Research Goals
- ❖ Typical Questions
- ❖ Some Definitions
- ❖ Approaches to Measuring Interoperability
 - Scorecard Approach
 - Levels of Information Systems Interoperability (LISI)
 - Management Performance Measures
- ❖ Next Steps



Technical Interoperability Scorecard



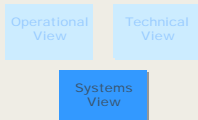
System	Compliance [†]
S ₁	R
S ₂	Y
S ₃	G
S ₄	G
S ₅	R
S ₆	Y
⋮	⋮
S _n	R

Adapted from [Committee 99]

[†] The entries rate as pass/marginal/fail (green, yellow, or red) the compliance of systems S₁, S₂ ... S_n with the relevant standards and guidance.



Systems Interoperability Scorecard



	S1	S2	S3	S4	S5	...	S _n
S1							
S2	G						
S3	Y	R					
S4	Y	G	N/A				
S5	G	G	R	Y			
⋮	⋮	⋮	⋮	⋮	⋮		
S _n	G	Y		G	G		

The entries rate as pass/marginal/fail (green, yellow, or red) the pairwise interoperability of the systems indicated in the row and column headings.

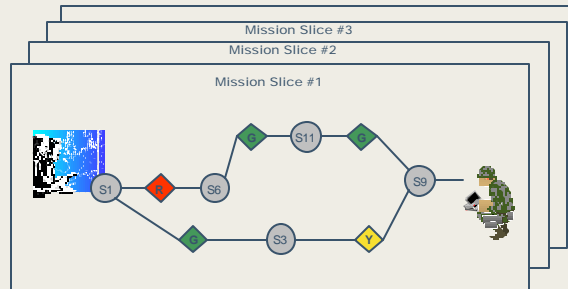


Operational Interoperability Scorecard

Operational
View

Technical
View

Systems
View



The diamonds rate as pass/marginal/fail (green, yellow, or red) the ability of the systems (indicated as circles) to provide the required information flows (indicated by arrows) for a particular mission slice.



Presentation Outline

- ❖ Introduction to the Problem
- ❖ SEI's Research Goals
- ❖ Typical Questions
- ❖ Some Definitions
- ❖ Approaches to Measuring Interoperability
 - Scorecard Approach
 - Levels of Information Systems Interoperability (LISI)
 - Management Performance Measures
- ❖ Next Steps



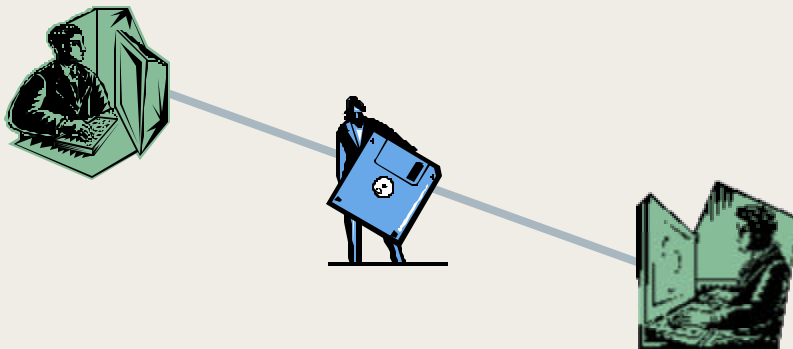
Levels of Information Systems Interoperability [LISI]

- Project initiated by MITRE, The C4ISR Integration Task Force, and the C4ISR Architecture Working Group
- LISI is a reference model and process for assessing information systems' interoperability.
- It provides a discipline for defining, measuring, assessing, and certifying the degree of interoperability required or achieved between systems.



Level 0: Isolated

Manual gateway





Carnegie Mellon
Software Engineering Institute

Level 1: Functional

Email, FM voice, tactical data links, text files



Carnegie Mellon
Software Engineering Institute

Level 2: Functional

Annotated imagery, maps w/ overlays

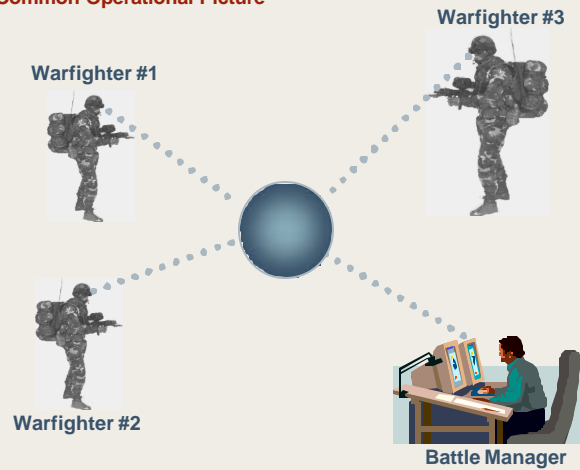




Carnegie Mellon
Software Engineering Institute

Level 3: Domain

Common Operational Picture



© 2003 by Carnegie Mellon University

19



Carnegie Mellon
Software Engineering Institute

Level 4: Enterprise

Event-triggered global database update



© 2003 by Carnegie Mellon University

20

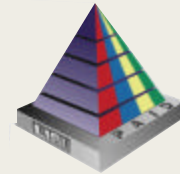


LISI Maturity Levels - Summary

- | | | |
|----------|-------------------|---|
| 4 | Enterprise | <ul style="list-style-type: none">• Cross-domain information & advanced collaboration• Interactive manipulation of shared data & applications |
| 3 | Domain | <ul style="list-style-type: none">• Shared data but separate applications• Sophisticated collaboration |
| 2 | Functional | <ul style="list-style-type: none">• Minimal common functions; separate data & applications• Heterogeneous product exchange• Basic collaboration |
| 1 | Connected | <ul style="list-style-type: none">• Electronic connected; separate data & applications• Homogeneous product exchange |
| 0 | Isolated | <ul style="list-style-type: none">• Non-connected• Homogeneous product exchange |



LISI Capabilities Model



Interoperability Attributes		
Description	Computing environment	Level
Enterprise	Universal	4
Domain	Integrated	3
Functional	Distributed	2
Connected	Peer-to-Peer	1
Isolated	Manual	0

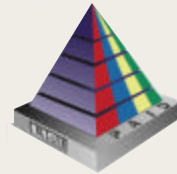


The PAID Attributes

- P** Policies and procedures that enable systems to exchange information capabilities and services
- Standards
 - Management
 - Security Policy
 - Operations
-
- A** The set of applications that enable information exchange, processing, or manipulation (based on user requirements).
-
- I** The infrastructure required to support the systems operations
- Communications and Networks
 - Hardware
 - System Services
 - Security Equipment
-
- D** The data and information structures used to support both the functional applications and system infrastructure
-



LISI Capabilities Model



Interoperability Attributes		
Description	Computing environment	Level
Enterprise	Universal	4
Domain	Integrated	3
Functional	Distributed	2
Connected	Peer-to-Peer	1
Isolated	Manual	0



LISI Capabilities Model

Level (Environment)		Interoperability Attributes				
		P	A	I	D	
Enterprise Level (Universal)	4	c	Multi-National Enterprises	Interactive (Cross applications)	Multi-Dimensional Topologies	Cross-Enterprise Models
		b	Cross Government Enterprises			Enterprise Models
		a	DoD Enter Prises			
Domain Level (Integrated)	3	c	Domain (Service/Agency Doctrine, Procedures, Training)	Shared Data (e.g., Simulation Displays, Direct DB exchange)	LAN	DBMS
		b	Group Collaboration Full Text Cut & Paste	Domain Models		
		a				
Functional Level (Distributed)	2	c	Common Operating Environment (e.g., DISCOE Level 5 Compliance)	Web Browser	Program Models and Advanced Data Formats	
		b	Basic Operations (Documents, Spreadsheets, Pictures, etc.)			
		a	Program (Standard Procedures, Training, etc.)	Advanced Messaging (Message Parsers, Email w/ attachments)		
Connected Level (Peer-to-Peer)	1	d	Standards Compliant (e.g., JTA)	Basic Messaging (e.g., Simple Text)	Two-Way	Basic Data Formats
		c	Security Profile	Data File Transfer		
		b		Simple Interaction (e.g., Telemetry, Remote Access, Voice Fax)	One Way	
		a				
Isolated Level (Manual)	0	d	Media Exchange Procedures	N/A	Removable Media	Media Formats
		c	Manual Access Controls		Manual Re Entry	Private Data
		b				
		a				
		0				

Example Implementation Options Table

WAN

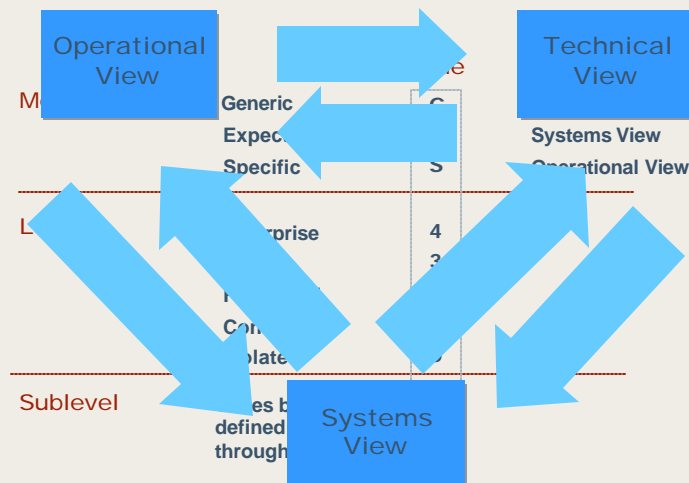
- SIPRNET
- JWICS
- NIPRNET
- (Internet)
- DISN LES
- VSAT
- DISN

NET

- Link 16
- Link 22
- UHF Radio
- VHF Nets
- Ethernet
- Token Ring
- Other Nets



The LISI Metric





Example LISI Profile & Resulting Metric for Single System

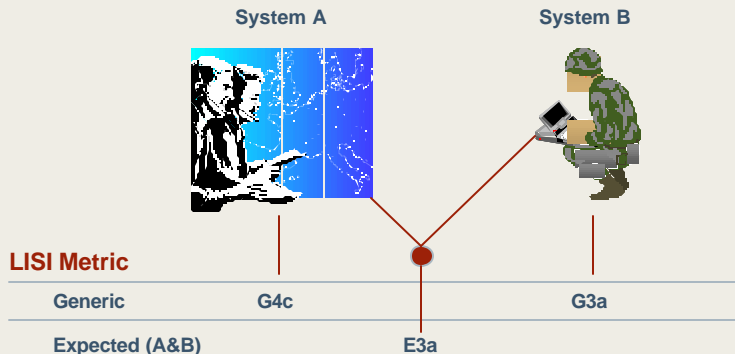
Level (Environment)		Interoperability Attributes			
		P	A	I	D
Enterprise Level (Universal)	4	c			
	b				
	a				
Domain Level (Integrated)	3	c	Service-approved MNS & ORD, WAN addressing scheme	TCP/IP WAN, NFS, SNMP, ISDN card	MIDB, SQL
	b				
	a				
Functional Level (Distributed)	2	c	DII COE Compliant, Windows-std file name extensions	IE 4.0	NIFT.2 USMTF, x.400, .wks, .xls, DTED, DBDB, .ppt, .doc, RPF, CGM, JBIG, JPEG, HTML, VPF
	b		MS Office, Access CMTK, 5D, MPEG Viewer	IPLAN NES NTP.X.500	
	a		On line Documentation	Eudora TBS, LINK 16 & 22	
Connected Level (Peer-to-Peer)	1	d	Windows Interface Design Guide (JTA)		
	c		FTP	HF Data Modem, Kermit, STU III, GSM Cellular	MPEG 1.2 GKS, wmf
	b		ITU-T Rec X.509, Mil Std 2045-28500 Security Labels	Chat 2.0 Win32 API,PPS	
Isolated Level (Manual)	0	d	Login procedures		
	c				
	b				
	a				
	0				
No known interoperability					

System
generic
metric is
"G2c"



When Comparing Two Systems

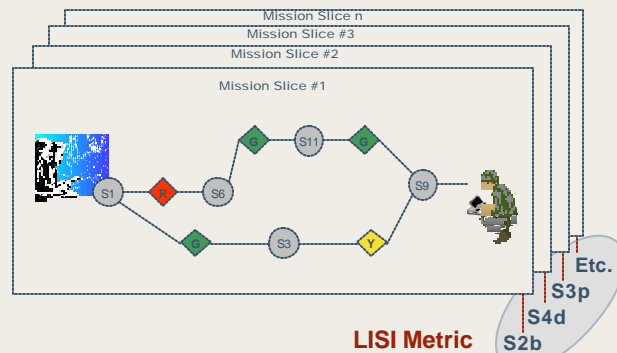
The LISI metric is simply the lesser of the two systems' generic levels. This is the **expected** LISI metric.





Two Systems in Operational Use

This LSI metric takes into account the environmental factors and specific mission requirements. This is the **specific** LSI metric.



Operational Detailed Measures of Interest - Examples

Connectivity

Capacity

System Overload

Underutilization

Undercapacity

Data latency

Information interpretation & utilization

$$Q_{eff} = (Q_{max} - Q_{oh}) \times (t_f - t_p)$$

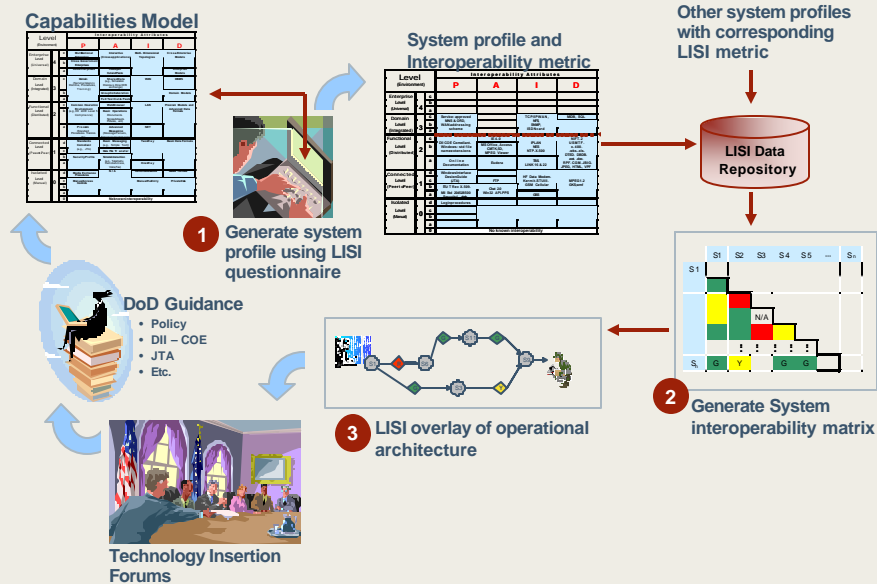
Where:

Q_{eff} = Effective system capacity (data rate)

Q_{max} = Maximum data rate

Q_{oh} = System overhead data rate

- Percentage of initial transmission messages received correctly by shooters
- Percentage of consistency/disparity of redundant data sources
- Number of tries needed to establish connections
- Delay in sending critical command messages and time to receive acknowledge messages



Presentation Outline

- ❖ Introduction to the Problem
- ❖ SEI's Research Goals
- ❖ Typical Questions
- ❖ Some Definitions
- ❖ Approaches to Measuring Interoperability
 - Scorecard Approach
 - Levels of Information Systems Interoperability (LISI)
 - Management Performance Measures
- ❖ Next Steps



Measuring Management Commitment to Interoperability

The Committee to Review DoD C4I Plans and Programs found that:

“achieving C4I interoperability is more a matter of organizational commitment and management than one of technology”

Potential management measures

- Number of systems certified to be interoperable
- Time (or personnel required to develop time-phased force and deployment data
- Time need to stand up a tactical network for a joint task force
- Number of individuals trained in the use of specific C4I systems



Next Steps

- 1 Establish collaborative relationships with stakeholders who are conducting interoperability assessments.
- 2 Provide guidance for measurement aspects of the assessment process(es).
- 3 Pilot the process using measures developed in stage 2.
- 4 Conduct a lessons learned to evaluate the utility of the measures that were piloted.
- 5 Assess the results of the pilot study, develop recommendations and publish the results for the community.



References

- [C4ISR 98] C4ISR Architecture Working Group, "Levels of Information Systems Interoperability (LISI)." 1998. Available online at http://www.c3i.osd.mil/org/cio/i3/AWG_Digital_Library/.
- [Chatfield 98] Chatfield, J., Enyeart, C., and Ficks, W. "New Architecture Directions." The Edge Newsletter. January, 1998. Available online at http://www.mitre.org/pubs/edge/january_98/fifth.htm.
- [Committee 99] Committee to Review DoD C4I Plans and Programs. "Realizing the Potential of C4I." National Academy Press. Washington, D.C. 1999.
- [Quinlan 00] Quinlan, Robin. "Weapon Systems Interoperability: Evolving Capability to Support the Warfighter." April, 2000. Available online at <http://jrtc.fhu.disa.mil/>.